DESY 96-019 ISSN 0418-9833
February 1996



# Soft Colour Interactions and the Diffractive Structure Function[1]

A. Edin[a], G. Ingelman[a,b], J. Rathsman[a]

[a]*Dept. of Radiation Sciences, Uppsala University, Box 535, S-751 21 Uppsala, Sweden*
[b]*Deutsches Elektronen-Synchrotron DESY, Notkestrasse 85, D-22603 Hamburg, Germany*

**Abstract:** We discuss our model for soft colour interactions and present results on the diffractive structure function $F_2^D(\beta, x_{I\!P}, Q^2)$ and inclusive transverse energy flows, which agree with available HERA data.

The observation of rapidity gap events at HERA [1, 2] has led to a renewed interest in diffractive phenomena and how they can be understood within QCD. In [3] we presented a new model for diffractive hard scattering based on a mechanism for soft colour interactions (SCI). The starting point is the normal DIS parton level interactions, with perturbative QCD corrections based on standard first order matrix elements and conventional leading log parton showers for higher order parton emission. This gives a state of colour-ordered partons that will have further non-perturbative interactions to produce the final hadron state. The novel feature in our model is the introduction [3] of random soft colour interactions corresponding to non-perturbative gluon exchange between these partons. This changes the colour structure and thereby affects the hadronic final state when a conventional hadronisation model such as the Lund string model [4] is applied.

Rapidity gaps may then arise when a gap at the parton level is not spanned by a string. In particular, when the hard process starts with a gluon from the proton, leaving a colour octet remnant and a colour octet hard scattering system, a soft colour exchange between the two octet systems can give two colour singlets separated in rapidity [3]. Large forward rapidity gaps are here favoured by the large momentum of the remnant, in particular at small-$x$. Our model [5] is implemented in the Monte Carlo (MC) Lepto 6.4 producing complete events.

To compare our model with experimental data on rapidity gap events we consider the diffractive structure function $F_2^D(\beta, x_{I\!P}, Q^2)$ defined by [6]

$$\frac{d\sigma^D}{d\beta dx_{I\!P} dQ^2} = \frac{4\pi\alpha^2}{\beta Q^4}\left[1 - y + \frac{y^2}{2}\right] F_2^D(\beta, x_{I\!P}, Q^2) \tag{1}$$

(i.e. assuming single photon exchange and neglecting $F_L$). This inclusive quantity contains the dependence on the main variables $\beta \simeq Q^2/(Q^2 + M_X^2)$, $x_{I\!P} \simeq (Q^2 + M_X^2)/(Q^2 + W^2)$ and the usual DIS momentum transfer squared $Q^2$. The acceptance corrected data from H1 [2] are compared in Fig. 1 to our model results obtained by selecting MC events with rapidity gaps similar to the H1 definition (i.e. no energy in $\eta_{max} < \eta < 6.6$ where $\eta_{max} < 3.2$).

The model is generally in good agreement with the data. It has a tendency to be below the data at large $Q^2$, possibly due to slightly too much parton radiation. The $\beta$-dependence seems to be the same in the model and the data and thereby the $M_X$ dependence is also basically correct. The $x_{I\!P}$-dependence in the model may be slightly steeper than in the data. Fitting a universal $x_{I\!P}^{-a}$-dependence we get $a = 1.5 \pm 0.2$ from our model to be compared with the H1

[1]Presented by G. Ingelman at Workshop on 'HERA Physics – Proton, Photon and Pomeron Structure', Durham, September 1995, to appear in the proceedings.

result $a = 1.2 \pm 0.1$ [2] and ZEUS results $a = 1.3 \pm 0.1$ [1] and $a = 1.5 \pm 0.1$ [7] using different methods. However the result obtained in the model depends significantly on which $x_{I\!P}$-bins that are included in the fitting procedure. This originates from the model not quite giving a straight line in this plot, but having a tendency for a curvature with smaller slope at small $x_{I\!P}$ and larger slope at large $x_{I\!P}$. With improved experimental data this aspect of the model can be tested.

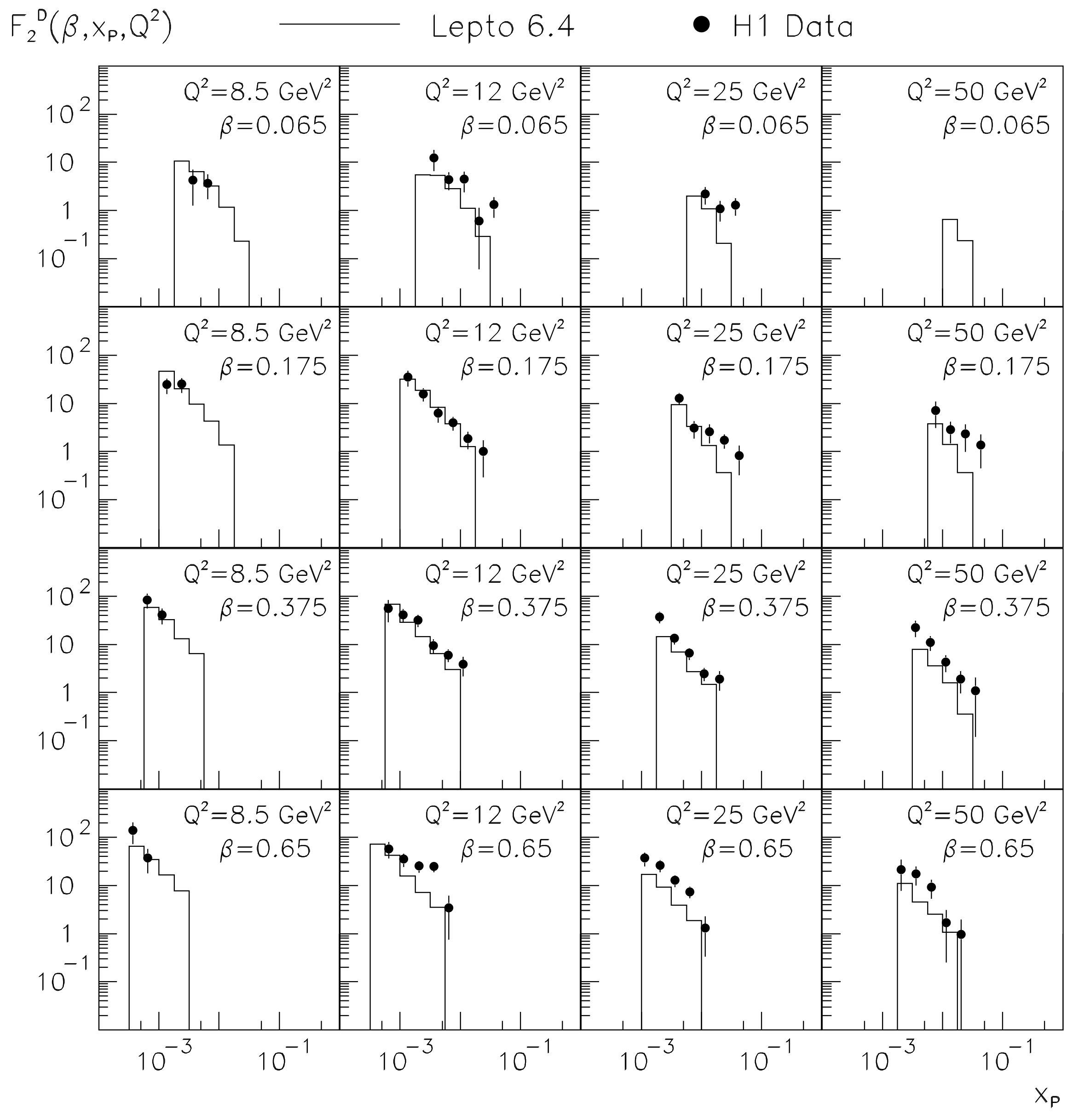


Figure 1: The diffractive structure function $F_2^D(\beta, x_{I\!P}, Q^2)$ from our soft colour interaction model (histograms) compared to the H1 data points [2].

Our model is meant to be applicable for DIS in general and should therefore also be compared with normal DIS events. The observed large forward transverse energy flow in an inclusive event sample requires a substantial energy and particle production and is thereby 'orthogonal' to forward rapidity gaps. In Fig. 2 we compare our model result with the H1 data [8]. The agreement is quite good except for the smallest $x$-values where the model is below the data in the central region of the hadronic cms.

The possibility to obtain rapidity gaps depends on to which extent there are gaps at the parton level, i.e. on the amount of parton emission in the forward region. In our model we use the first order QCD matrix elements for the primary emission and therefore the treatment of their soft and collinear divergences is of importance. We have replaced the conventional requirement $m_{ij}^2 > y_{cut}W^2$ on any pair $ij$ of partons with an advantageous 'mixed' scheme using cuts in $\hat{s} = (p_1 + p_2)^2$ and $z = p_1 P/qP$ which handles initial state collinear singularities better [5]. Numerically we use $\hat{s}_{\min} = 1$ GeV$^2$ and $z_{\min} = 0.01$.

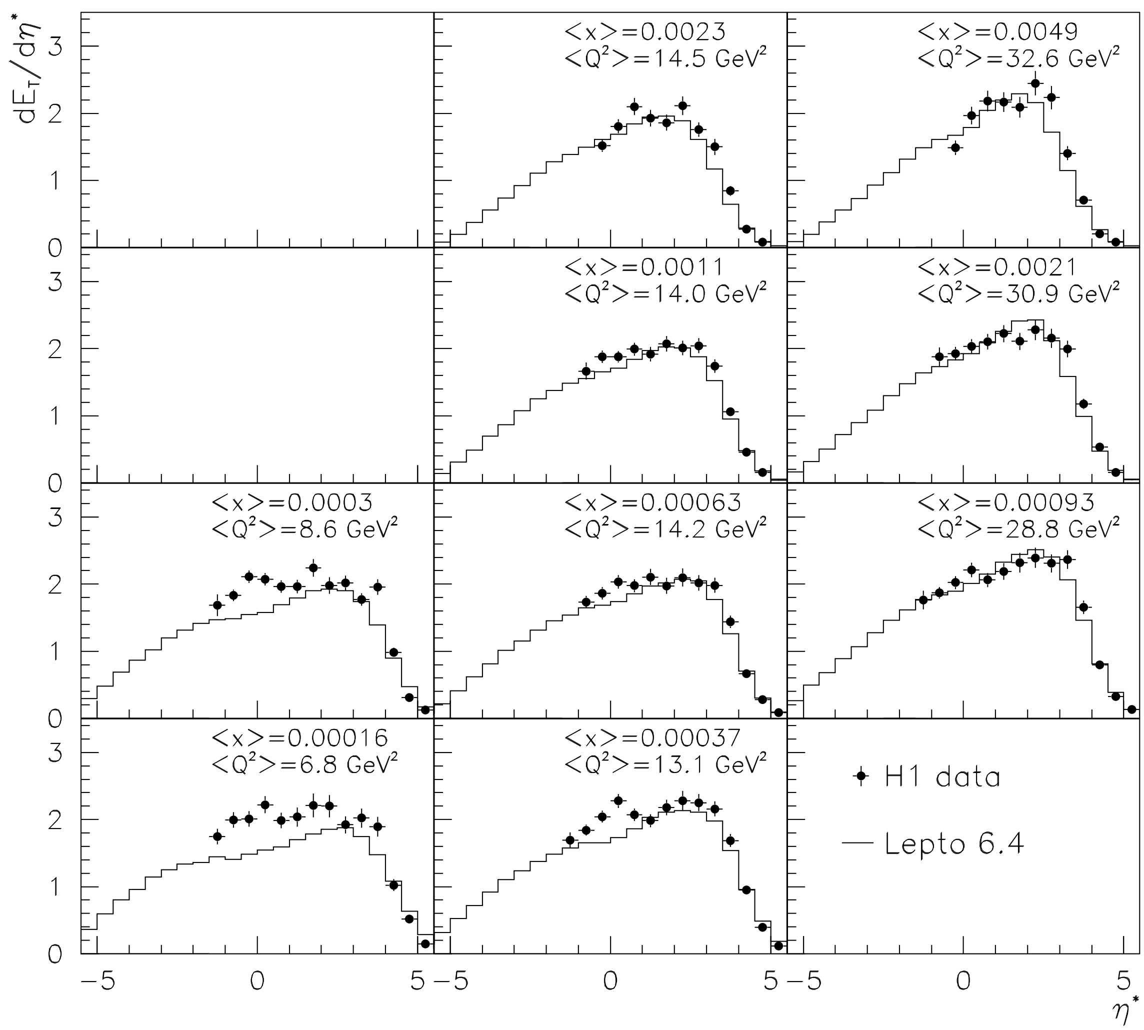


Figure 2: Transverse energy flow versus pseudorapidity $\eta^*$ in the hadronic cms from our model (histograms) compared to H1 data points [8].

Higher order parton emissions are taken into account approximately through parton showers developing from the incoming and scattered parton. The initial state shower is most important for the forward rapidity region. In our model we are using the conventional GLAP evolution scheme [10] summing leading $\log Q^2$ terms. Terms with $\log(1/x)$ are neglected in GLAP, but will become important at small $x$ and should then be resummed as in the BFKL equation [11]. Therefore GLAP evolution should no longer be valid at some small $x$. Recent studies [12] based on the CCFM equation [13] which sums both leading $\log Q^2$ and $\log(1/x)$ terms suggests that this happens only at very small $x$, below the region $10^{-4} \lesssim x \lesssim 10^{-2}$ where the rapidity gap events

are observed. Thus, there is no strong reason that the GLAP formalism should not be applicable for our purposes.

One may worry that unsuppressed parton emission will destroy the gaps [9]. The cut-off in parton virtuality, defining the borderline to the non-perturbative region, is a regulator of this. We have previously [3] used the value 2 GeV, but in our improved model [5] returned to 1 GeV, which has been standard and conforms with e.g. LEP analyses. Thus, our model works with a conventional unsuppressed GLAP parton shower.

Of importance for the gap rate is also the fluctuations in the initial parton emission [3]. Although, one may expect that a GLAP parton shower gives a fair mean description of events, there is no guarantee that it accounts properly for fluctuations. Larger fluctuations of the number of emitted gluons would increase the rate of gap events and also increase the inclusive forward energy flow due to 'downwards' and 'upwards' fluctuations, respectively.

In summary, our model based on non-perturbative soft colour interactions can explain important features of both rapidity gap events and normal DIS interactions at HERA.

## References


[1] ZEUS Coll., Phys. Lett. B315 (1993) 481; Z. Phys. C68 (1995) 569

[2] H1 Collaboration, Nucl. Phys. B429 (1994) 477; Phys. Lett. B348 (1995) 681

[3] A. Edin, G. Ingelman, J. Rathsman, DESY 95-145 to appear in proc. 'DIS and QCD', Paris, April 1995; DESY 95-163 to appear in Phys. Lett. B

[4] B. Andersson et al., Phys. Rep. 97 (1983) 31

[5] A. Edin, G. Ingelman, J. Rathsman, in preparation

[6] G. Ingelman, K. Prytz, Z. Physik C58 (1993) 285

[7] ZEUS Coll., Contribution to the Beijing Conference, August 1995

[8] H1 Collaboration, Phys. Lett. B356 (1995) 118

[9] L. Lönnblad, these procedings, hep-ph/9512373

[10] V.N. Gribov, I.N. Lipatov, Sov. J. Nucl. Phys. 15 (1972) 438
G. Altarelli, G. Parisi, Nucl. Phys. B126 (1977) 298

[11] E.A. Kuraev, L.N. Lipatov, V.S. Fadin Sov. Phys. JETP 45 (1977) 199
Ya. Ya. Balitsky, L.N. Lipatov, Sov. J. Nucl. Phys. 28 (1978) 822

[12] B. Andersson et al., Lund preprint LU TP 95-34

[13] M. Ciafaloni, Nucl. Phys. B296 (1988) 49
S. Catani, F. Fiorani, G. Marchesini, Phys. Lett. B234 (1990) 339;
Nucl. Phys. B336 (1990) 18